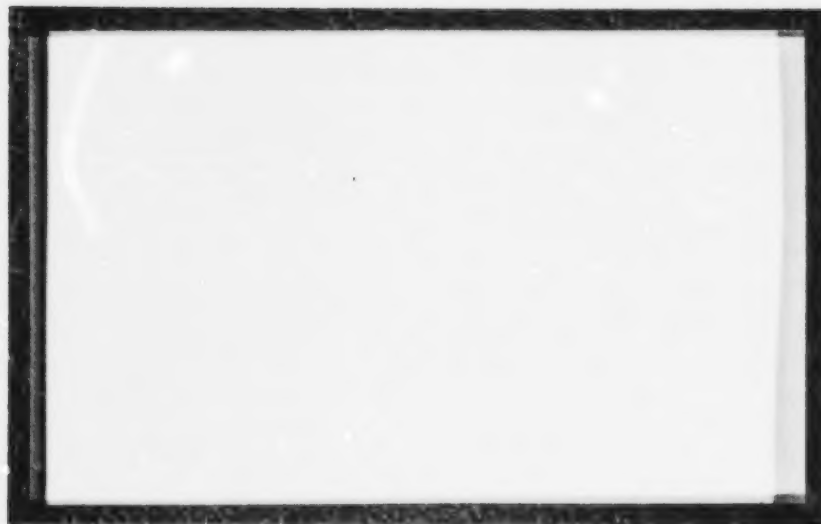


UNIVERSITÉ DE MONTRÉAL



CENTRE DE RECHERCHE SUR LES TRANSPORTS



CASE POSTALE 6128, SUCCURSALE A, MONTRÉAL, QUÉBEC, H3C 3J7

CRT-586

ON THE APPROPRIATE OUTPUT MEASURE
IN THE TRUCKING INDUSTRY

by

Robert Gagné*

* Centre de recherche sur les transports et département de Sciences économiques, Université de Montréal.

I would like to thank F.C.A.R.-Québec (Action concertée/Transport des marchandises) and Transport Canada for their financial support. I am also indebted to Georges Dionne and Bryan Campbell for their helpful comments.

Cette étude a été publiée grâce à une subvention du fonds F.C.A.R. pour l'aide et le soutien à la recherche.

Université de Montréal
Centre de recherche sur les transports - Publication #586
July 1988

Dépôt légal - 3e trimestre 1988

ABSTRACT

The effects of output qualities on costs of trucking firms are not independent of the choice of the output measure used. This paper shows that the total number of shipments is a more appropriate measure than the total ton-kilometers carried by firms.

Key-words: trucking industry; cost function; output measure.

- - - - -

RÉSUMÉ

Dans cette note, il est démontré que l'effet de certaines qualités de la production sur les coûts des entreprises de transport par camion dépend de la mesure de production utilisée. De fait, il est montré que la mesure de production la plus appropriée est le nombre total d'expéditions effectuées par les entreprises.

Mots-clés: transport par camion; fonction de coût; mesure de production.

1. Introduction

Most of the empirical studies of the technology structure of the trucking industry rely on estimated cost functions obtained through a cross-sectional sample of firms¹. However, since output in this industry is by nature heterogeneous, single aggregate output cost functions are not appropriate. For example, if total ton-kilometers carried by firms are considered the appropriate measure of aggregate output, two firms with the same level of output could very well have different total costs even when facing the same input prices: one firm could specialize in less-than-truck-load (LTL) shipments over short distances, while the other in truckload (TL) shipments over long distances. Moreover, part of the difference in costs could be attributed to the difference in the mix of commodities carried by each firm. In order to take these characteristics into account, Spady and Friedlaender (1978) have introduced measures of output qualities into the cost function. Through a hedonic function which has as arguments output qualities variables "observed" aggregate output (total ton-kilometers) is converted into "effective" aggregate output. Effective output is then introduced into the cost function, a feature of what is commonly called a hedonic or technological cost function.

Since total ton-kilometers carried by firms is, by construction, the product of the number of shipments and two output qualities (average length of haul and shipment size), the use of ton-kilometers as observed aggregate output can lead to a false interpretation of the effects of these qualities on costs. Suppose, for instance, that we are interested in the effect of an increase in the average length of haul on costs. This effect could be measured by the elasticity of costs with respect to average length of haul. But, since the elasticity is evaluated at both a given number of ton-kilometers and a given average shipment size, an increase of the average length of haul cannot take place without a decrease in the number

¹ See, for instance, Spady and Friedlaender (1978,1981), Friedlaender and Wang Chiang (1983), Kim (1984), Friedlaender and Schur Bruce (1985), and Daughety, Nelson and Vigdor (1985).

of shipments. Therefore, the computed effect is the sum of two distinct effects: the effect due to the augmentation of average length of haul (which is the "true" effect) and the effect due to the diminution of the number of shipments.

In this note, we present theoretical and empirical evidence which supports the use of the number of shipments rather than total ton-kilometers as the appropriate measure of observed aggregate output of the firm. This alternative measure has the advantage of yielding the "true" effects of output qualities on costs while preserving results regarding the elasticity of cost with respect to observed aggregate output. Conclusions on returns to scale are not affected.

2. Elasticities of cost with respect to output and output qualities

Consider the following cost function:

$$C = C(Y, w, q) \quad [1]$$

where C is total cost,
 Y is total ton-kilometers carried by firms,
 w is a vector of input prices,
 q is a vector of output qualities.

In most of the studies cited above, the vector of output qualities contains the following variables: average length of haul, average shipment size, average load per truck, percentage tons shipped in LTL lots and insurance cost per ton-kilometer. These qualities are included into the cost function in order to take into account the heterogeneous nature of output in the trucking industry.

Since we do not have a priori knowledge of the specific functional form of the cost function, relation [1] can be approximated by a translog form which represents a second-order Taylor series approximation to an unknown function. The translog form of [1] is given by:

$$\begin{aligned}
 \ln C(Y, q, w) = & \alpha_0 + \alpha_Y \ln(Y/\bar{Y}) + \sum_{s=1}^m \beta_s \ln(w_s/\bar{w}_s) + \sum_{u=1}^k \gamma_u \ln(q_u/\bar{q}_u) \\
 & + \frac{1}{2} A_{YY} (\ln(Y/\bar{Y}))^2 + \frac{1}{2} \sum_{s=1}^m \sum_{t=1}^m B_{st} \ln(w_s/\bar{w}_s) \ln(w_t/\bar{w}_t) \\
 & + \frac{1}{2} \sum_{u=1}^k \sum_{v=1}^k C_{uv} \ln(q_u/\bar{q}_u) \ln(q_v/\bar{q}_v) + \sum_{s=1}^m D_{Ys} \ln(Y/\bar{Y}) \ln(w_s/\bar{w}_s) \\
 & + \sum_{u=1}^k E_{Yu} \ln(Y/\bar{Y}) \ln(q_u/\bar{q}_u) + \sum_{s=1}^m \sum_{u=1}^k F_{su} \ln(w_s/\bar{w}_s) \ln(q_u/\bar{q}_u)
 \end{aligned} \quad [2]$$

where a bar stands for the arithmetic mean of the variables¹. The usual homogeneity and symmetry restrictions should be imposed on [2] prior to its estimation.

q_1 - the average length of haul - may be computed as follows:

$$q_1 = Y/W, \quad [3]$$

where Y is defined as above and

W is the total weight (in tons) carried by the firms.

Moreover, if we define q_2 as the average shipment size with:

$$q_2 = W/N \quad [4]$$

where N is the total number of shipments,

then observed aggregate output could be written as the product of N , q_1 and q_2 :

$$Y = N q_1 q_2. \quad [5]$$

Almost all the studies cited above compute q_1 and q_2 using [3] and [4].

¹ m and k are respectively the dimensions of input vector w and output qualities vector q .

The form of the translog cost function enables us to compute directly the elasticities of cost with respect to output and output qualities. The elasticity of cost with respect to total ton-kilometers is given by:

$$\frac{\partial \ln C(Y, q, w)}{\partial \ln Y} = \alpha_Y + A_{YY} \ln(Y/\bar{Y}) + \sum_{s=1}^m D_{Ys} \ln(w_s/\bar{w}_s) + \sum_{u=1}^k E_{Yu} \ln(q_u/\bar{q}_u) . \quad [6]$$

At the point of approximation ($Y=\bar{Y}$, $w_s=\bar{w}_s$ and $q_u=\bar{q}_u$), this elasticity is equal to α_Y .

Now, since $\ln Y = \ln N + \ln q_1 + \ln q_2$ we can also compute the elasticity of cost with respect to N (the total number of shipments):

$$\frac{\partial \ln C(Y, q, w)}{\partial \ln N} = \frac{\partial \ln C(Y, q, w)}{\partial \ln Y} \frac{\partial \ln Y}{\partial \ln N} = \frac{\partial \ln C(Y, q, w)}{\partial \ln Y} , \quad [7]$$

since $\partial \ln Y / \partial \ln N = 1$. As shown in [7], the elasticity of cost with respect to output is not affected by the output measure used (Y or N). However, this conclusion is not valid for the elasticities of cost with respect to specific output qualities. These latter are given by:

$$\frac{\partial \ln C(Y, q, w)}{\partial \ln q_u} = \frac{\partial \ln C(Y, q, w)}{\partial \ln q_u} + \frac{\partial \ln C(Y, q, w)}{\partial \ln Y} \frac{\partial \ln Y}{\partial \ln q_u} . \quad [8]$$

For output qualities other than average length of haul and average shipment size $\partial \ln Y / \partial \ln q_u = 0$. Therefore, from [2], the elasticities of cost with respect to output qualities other than average length of haul and average shipment size are:

$$\frac{\partial \ln C(Y, q, w)}{\partial \ln q_u} = \gamma_u + \sum_{v=1}^k C_{uv} \ln(q_v/\bar{q}_v) + E_{Yu} \ln(Y/\bar{Y}) + \sum_{s=1}^m F_{su} \ln(w_s/\bar{w}_s) , \quad u=3, \dots, k . \quad [9]$$

Again, at the point of approximation, these elasticities are equal to γ_u ($u=3, \dots, k$).

Let us now examine the special case of output qualities 1 and 2. Since for these qualities $\partial \ln Y / \partial \ln q_u = 1$, equation [9] is no longer correct. The appropriate measure is given by:

$$\begin{aligned} \frac{\partial \ln C(Y, q, w)}{\partial \ln q_u} &= \alpha_Y + \gamma_u + (A_{YY} + E_{YU}) \ln(Y/\bar{Y}) \\ &+ \sum_{v=1}^k (C_{uv} + E_{YV}) \ln(q_v/\bar{q}_v) \\ &+ \sum_{s=1}^m (D_{Ys} + F_{su}) \ln(w_s/\bar{w}_s), \quad u=1, 2. \end{aligned} \quad [10]$$

At the point of approximation, these elasticities are equal to $\alpha_Y + \gamma_u$ ($u=1, 2$).

3. Empirical evidence

In order to illustrate the differences in the magnitudes of the elasticities computed by [9] and [10], we have estimated equation [2]. The regression was undertaken using a sample of 403 trucking firms from the provinces of Quebec and Ontario². The following variables were included in the cost function:

- Y : observed aggregate output (ton-kilometers);
- w_1 : price of fuel;
- w_2 : price of labour;
- w_3 : price of capital;
- w_4 : price of materials;

¹ In all the studies mentioned above, relation [9] was used to compute the elasticities of cost with respect to all output qualities, including average length of haul and average shipment size.

² Details about the sample are available from the author.

- q_1 : average length of haul (kilometers);
- q_2 : average shipment size (tons);
- q_3 : capacity utilization (tons/vehicle-kilometers);
- q_4 : insurance (insurance cost/ton-kilometers);
- C : total costs.

Equation [2] was estimated with its corresponding input share equations, using the iterative version of the Zellner (1962) procedure. Moreover, since input shares sum to 1, an input share equation was deleted in the estimation procedure in order to avoid the singularity of the estimated disturbance covariance matrix.

The first column of Table 1 presents the first-order parameter estimates of [2]¹.

Table 1
Cost Function First-Order Parameter Estimates and Elasticities
(t-ratios in parentheses)

Variables	Parameters	Elasticities
Constant	17,1691 (191,06)	—
γ	0,9636 (24,58)	0,9636 (24,58)
w_1	0,1059 (16,32)	0,1059 (16,32)
w_2	0,2080 (21,05)	0,2080 (21,05)
w_3	0,3010 (29,08)	0,3010 (29,08)
w_4	0,3851 (29,07)	0,3851 (29,07)
q_1	-0,5872 (-6,37)	0,3764 (4,95)
q_2	-0,1403 (-3,38)	0,8233 (14,33)
q_3	-0,3752 (-5,01)	-0,3752 (-5,01)
q_4	0,1129 (2,76)	0,1129 (2,76)

¹ Detailed results are available upon request.

The second column of Table 1 presents the elasticities of cost with respect to all the variables evaluated at the point of approximation $(\bar{Y}, \bar{w}, \bar{q})$. Elasticities with respect to average length of haul and average shipment size were computed using [10]. Elasticities are equal to first-order parameters except for output qualities 1 and 2. In that case, elasticities are now equal to $\alpha_Y + \gamma_1$ and $\alpha_Y + \gamma_2$. Therefore, even if first-order parameters of output qualities 1 and 2 are negative and significant, the elasticities of cost with respect to these variables are positive and significant. This difference is attributable to the fact that γ_1 and γ_2 give elasticities evaluated for a given number of ton-kilometers, while the "true" elasticities are obtained when the total number of shipments is fixed. Therefore, it is preferable to consider total number of shipments as the appropriate measure of output rather than total ton-kilometers carried by firms.

4. Conclusion

The results presented here are important when assessing the effects of deregulation on the cost structure of trucking firms. It is a common belief that an important part of the effects of deregulation on costs could originate via output qualities. Therefore, correct measures of the effects of output qualities on costs are essential to an adequate assessment of the effects of deregulation. This note suggests that the use of ton-kilometers as the measure of observed aggregate output could lead to misinterpretations of potential output qualities effects. It is more accurate to use the total number of shipments as the basic measure.

5. References

- Daughety, A.F., Nelson, F.D. and Vigdor, W.R., 1985, An Econometric Analysis of the Cost and Production Structure of the Trucking Industry, in: A.F. Daughety ed., Analytical Studies in Transport Economics (Cambridge University Press, Cambridge) 65-95.

- Friedlaender, A.F. and Schur Bruce, S., 1985, Augmentation Effects and Technical Change in the Regulated Trucking Industry, 1974-1979, in: A.F. Daughety ed., Analytical Studies in Transport Economics (Cambridge University Press, Cambridge) 29-63.
- Friedlaender, A.F. and Wang Chiang, S.J., 1983, Productivity Growth in the Regulated Trucking Industry, in: T.E. Keeler ed., Research in Transport Economics I (JAI Press, London) 149-184.
- Kim, M., 1984, The Beneficiaries of Trucking Regulation Revisited, Journal of Law and Economics 27, 227-241.
- Spady, R. and Friedlaender, A.F., 1978, Hedonic Cost Functions for the Regulated Trucking Industry, Bell Journal of Economics 9, 159-179.
- Spady, R. and Friedlaender, A.F., 1981, Freight Transport Regulation (M.I.T. Press, Cambridge).
- Zellner, A., 1962, An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests of Aggregation Bias, Journal of the American Statistical Association 57, 348-368.